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ORIGINAL ARTICLE

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Meningiomas infiltrating the superior sagittal sinus: surgical considerations of 328 cases

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Abstract The aim of the study was to discuss our management strategy and results of patients affected by meningiomas infiltrating the superior sagittal sinus. We describe 328 patients with meningiomas that were infiltrating the superior sagittal sinus. All the patients were surgically treated. Patients with meningioma involving the anterior segment of the sinus underwent total sinus resection. Patients with meningioma that was infiltrating the middle and posterior third of the sinus had a complete sinus removal if the dural sinus was completely obliterated by meningioma and incomplete removal if the sinus was not occluded. The tumour removal was grade I according to Simpson's grading system in 193 cases and grade II or III in the remainder. The superior longitudinal sinus was totally resected in 215 patients and marginally resected in 113. The tumour reappeared in 38 patients. The number of re-interventions did not affect clinical outcome. The extent of removal significantly influenced the regrowth or recurrence rate. Our results suggest that the risks of aggressive surgery, with sinus reconstruction, may be avoided, and conservative surgery for meningiomas that are infiltrating but not obliterating the superior sagittal sinus may be a reasonable choice.

Keywords Meningioma · Recurrence · Regrowth · Superior longitudinal sinus · Superior sagittal sinus · Surgery

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Introduction

Meningiomas account for approximately 15–18% of all intracranial tumours [17]. They are potentially curable lesions when completely excised, but the recurrence rate for meningioma following macroscopically complete resection varies from 9% to 20% at 10 years [3]. The relation between the extent of the surgical excision and recurrence is particularly important in those meningiomas in which anatomical reasons make radical surgery dangerous. In the management of meningiomas that are infiltrating the superior sagittal sinus, the advantages of a radical resection should be weighed against the potential additional risks related to the opening of the sinus and its wall resection.

The aim of this report was to evaluate the immediate and long-term results of surgical treatment of 328 meningiomas involving the superior longitudinal sinus (SLS).

Materials and methods

Between January 1970 and December 2000, 1,550 histologically verified cases of intracranial meningiomas were operated on at our institution. Review of the patients' records, the operating notes, and the radiological materials yielded 328 (21%) cases of meningiomas that were infiltrating the superior sagittal sinus.

SLS infiltration was confirmed by digital subtraction angiography in all patients treated until 1995, and then by angio-MRI. After 1995, we performed angiography only if angio-MRI was not diriment. Angiograms were evaluated by neuroradiologist to assess: patency of occlusion of the sinus, the extent of occlusion, and the number of collateral anastomoses close to the insertion zone of the meningioma.

The completeness of surgical removal was estimated according to the grading system proposed by Simpson [20]. The grade of sinus resection was classified as total or marginal . The choice of a total or marginal sinus resection depended on the degree of the sinus obliteration and segment involved. More precisely, patients with meningioma involving the anterior segment of the SLS underwent

total sinus resection. Patients with meningioma that was infiltrating the middle and posterior thirds of the SLS had a complete sinus removal only if the sinus was completely obliterated, and had incomplete removal if the sinus was not obliterated.

All tumours were graded by a neuropathologist according to the WHO classification.

All the patients had both a clinical and a neuroimaging follow-up.

Clinical conditions were evaluated according to the daily life activity that was classified as summarised in Table 1. Daily life activity was evaluated in all patients before surgery, at discharge, and 3 months after surgery. In patients re-operated on for recurrence or regrowth, daily life activity was evaluated before the first operation and 3 months after the last operation. Regrowth was defined as resumption of growth of an incompletely removed tumour, and recurrence as reappearance of a tumour considered to have been completely removed.

In totally removed meningiomas, postoperative radiological follow-up consisted of CT or MRI 1 month and 6 months after surgery and then every year for the rest of the patient's life. In meningiomas that were not totally removed, postoperative follow-up consisted of CT or MRI 1 month and 3 months after surgery, every 6 months thereafter for 5 years, and then every year for the rest of the patient's life.

The time of recurrence/regrowth was calculated in all cases. Patients with regrowth/recurrence were submitted to surgery only if the meningioma was symptomatic or completely occluded the sinus.

Statistical analysis was done by χ^2 test.

Results

There were 189 female patients and 139 male. The average age at the first operation was 57 years (range 24 years to 83 years). No patients carried stigmata of neurofibromatosis. The average duration of symptoms was 14.6 months (range 3 months to 20 months). The most common presenting symptoms were motor deficits (58%) followed by seizures (46%).

The anterior third of the SLS was involved in 107 patients (32%), the middle third in 151 (46%), and the posterior third in 70 (21%). The principal attachments of the tumours are listed in Table 2.

Table 2 Principal dural attachment of tumours

Attachment	Parasagittal	Falx	SLS	Total
Anterior 3rd	47	38	22	107
Middle 3rd	69	43	39	151
Posterior 3rd	10	29	31	70

In all patients angiography and/or angio-MRI showed SLS infiltration. Neuroradiologically established sinus infiltration was always confirmed by surgical findings.

All patients received surgical treatment.

The SLS was totally resected in 215 patients and resected marginally in 113.

The tumour removal was grade I in 193 cases. This was possible with a complete sinus resection in 102 meningiomas involving the anterior third and in 91 meningiomas obliterating the middle (49) and posterior (42) third of the sinus. The tumour removal was grade II in 21 patients. This was possible with a complete sinus resection in four meningiomas involving the anterior third and in 17 meningiomas obliterating the middle and posterior third of the sinus. The tumour removal was grade III in 114 patients (Fig. 1). In these cases, the sinus was resected marginally in 113 patients, and completely in one. In this case meningiomas infiltrated the distal tract of the anterior cerebral artery (Table 3).

After surgery, nine patients showed impairment in their daily life activities, mainly motor deficits; 16 patients showed an improvement, and the remainder of the patients remained stable. Three months after surgery, clinical evaluation showed improvement of clinical conditions in 37 patients and impairment in none. Daily life activity before the first operation, at discharge, and 3 months after surgery is summarised in Table 4.

There was no operative mortality in our series. The early postoperative course was complicated by motor deficits in ten patients (3%). In seven patients this disturbance ceased within 3 months.

Histopathologically, 152 tumours were classified as benign meningothelial meningiomas, 25 as benign transitional meningiomas, 125 as benign fibroblastic meningiomas, and 26 as benign psammomatous meningiomas.

The surgical report on the extent of tumour removal was confirmed by control CT (99 patients) or MRI (229 patients) in all cases. The more recent radiological follow-up was performed with MRI in another 85 patients operated on in the CT era.

Table 1 Clinical conditions evaluated according to daily life activity

Daily life activity	Clinical condition
No disability	Normal activity, no neurological deficit
Slight disability	Slight limitation of previous activities, but patient cares for self
Moderate disability	Unable to carry out normal activity, requires occasional assistance and can undertake some needs
Severe disability	Patient cannot return to any previous activities, requires frequent care and considerable assistance
Complete disability	Patients with so severe a clinical deterioration that they are totally dependent on an assistant

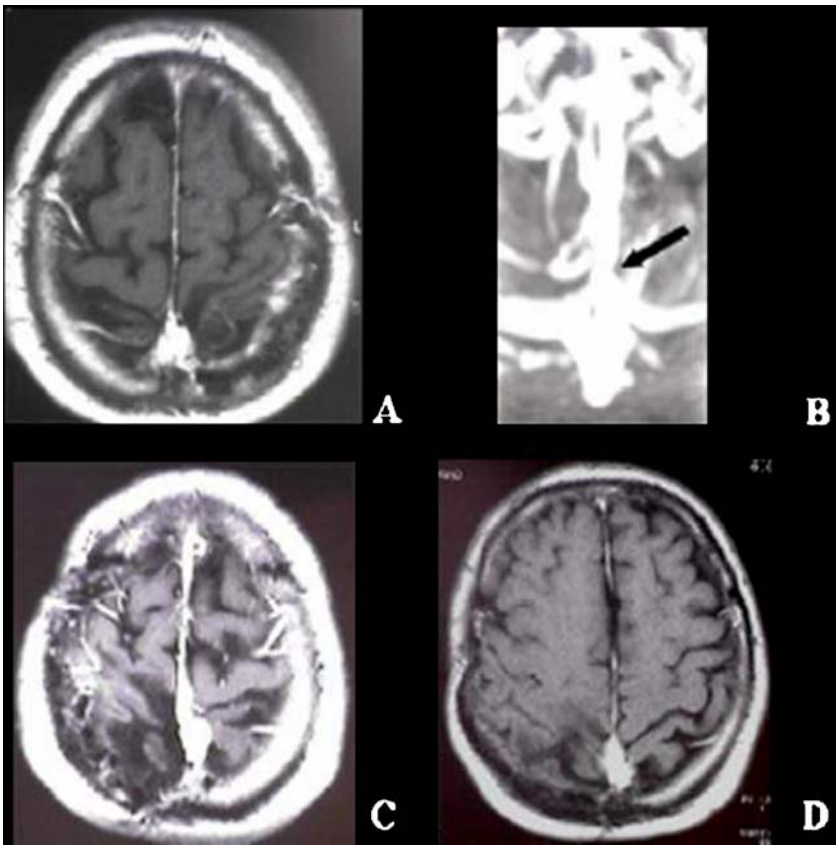

Fig. 1 A case of middle SLS meningioma (**a**) without occlusion of the SLS (**b**, *arrow*). Immediate (**c**) and late (**d**) postoperative MR images show stability of the residual tumour

The tumour progression and regrowth were always diagnosed before the appearance of clinical signs, by means of routine follow-up CT or MRI.

There were 49 incidences of recurrence/regrowth in 38 patients. Tumour recurrence occurred in 18 patients, and tumour regrowth in 20 (Fig. 2). Table 3 gives the rate of recurrence and regrowth for each degree of resection and segment of the SLS. Thirty patients had one recurrence/regrowth, five patients had two recurrences/regrowths, and three patients had three recurrences/regrowths. The number of recurrences/regrowths for each sinus segment is summarised in Table 5. Among the latter group, one patient exhibited atypical histological changes at reoperation.

Fourteen patients had no recurrence in situ, but a remote recurrence, that is, in a segment anterior or posterior to that of the primary meningioma.

The extent of removal significantly influenced the regrowth or recurrence ($P<0.001$).

Table 4 Daily life activity of 328 patients before and after the first operation

Daily life activity	Before surgery	At discharge	Three months after surgery
No disability	104	108	132
Slight disability	197	197	185
Moderate disability	25	20	9
Severe disability	2	3	2
Complete disability	–	-	–

Mean follow-up period was 25.4 years (range 3.5–34 years). Mean time for first recurrence/regrowth was 5.4 years (6.8 years after grade I removal, 4.7 years after grades II and III). Ten patients (27%) had a first recurrence/regrowth more than 10 years after diagnosis (all these

Table 3 Primary operations. Types of removal and related recurrence/regrowth rate

Status	Anterior 3rd		Middle 3rd		Posterior 3rd	
	Operation	Regrowth/ recurrence	Operation	Regrowth/ recurrence	Operation	Regrowth/ recurrence
Grade I	102	15	49	2	42	1
Grade II with sinus completely resected	4	3	10	3	7	3
Grade III with sinus marginally resected			92	6	21	4
Grade III with sinus completely resected	1	1				

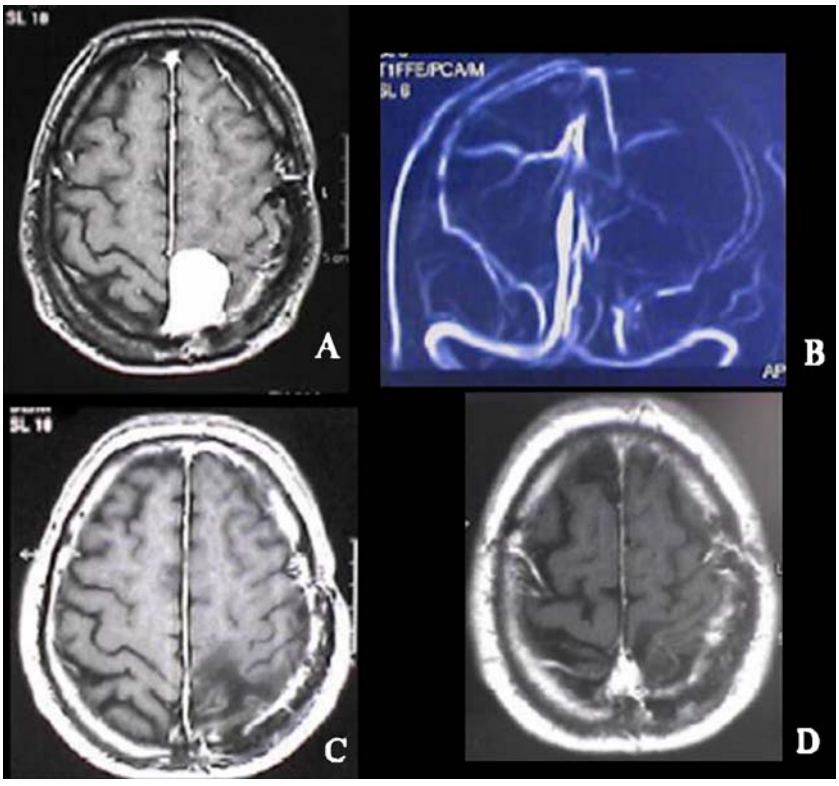

Fig 2 A case of middle SLS meningioma (**a**), with occlusion of the SLS (**b**). Immediate postoperative MR image shows no residual tumour (**c**). A late MR control image (**d**) shows a meningioma regrowth

patients had undergone a grade I resection). Mean time elapsed between first and second recurrence/regrowth and between second and third recurrence/regrowth was 3.1 years and 2.9 years, respectively.

The SLS was completely occluded at the time of the first recurrence/regrowth in 19 patients (50%). It was completely occluded at the time of the second recurrence/regrowth in four patients (50%). The sinus was completely obliterated in all patients at the third recurrence/regrowth. At the first recurrence, meningiomas with principal attachment on the SLS reached complete sinus obliteration more rapidly than parasagittal and falx meningiomas (14 patients versus two and three, respectively). This influenced surgery, because total sinus obliteration at the time of meningioma reappearance allowed grade I meningioma resection. An improvement (14 patients) or stability of clinical conditions was always observed at clinical evaluation before the first reoperation and 3 months after the last reoperation for tumour reappearance. These results are summarised in Table 6.

Table 5 Number of recurrences/regrowths

Location	One recurrence or regrowth	Two recurrence or regrowth	Three recurrence or regrowth
Anterior 3rd	16	1	2
Middle 3rd	7	3	1
Posterior 3rd	7	1	–

Discussion

It is universally accepted that postoperative meningioma recurrence is related to the microscopic pattern of the meningioma [7–10] and the adequacy of the original surgical removal [3, 15, 20]. In Simpson's series, grade I through grade IV tumours had recurrence rates of 9%, 19%, 29%, and 40%, respectively, at 10 years [20]. Unfortunately, Simpson grade I resection cannot always be performed if the meningioma involves vital structures. The invasion of the dural sinuses by meningiomas is a common event that may limit the extent of excision. The best surgical management of meningiomas involving the middle or posterior third of the sagittal sinus has not been established. The anterior third of the superior sagittal sinus, regardless its patency, can be ligated and divided without causing cerebral damage and neurological deficits [11]. On the other hand, the closure of the middle and posterior

Table 6 Daily life activity of 38 patients before and after the last operation for recurrence or regrowth

Daily life activity	Before surgery	Three months after surgery
No disability	20	29
Slight disability	11	5
Moderate disability	4	2
Severe disability	2	2
Complete disability	1	–

thirds of the superior sagittal sinus carries a significant risk of cortical venous infarction. Then, when these portions of sagittal sinus are patent, the surgeon must choose between two operating strategies:

– to attempt a total meningioma removal, restoring the venous outflow
– to leave residual meningioma and await sinus occlusion by the tumour and the development of collateral flow

Many techniques of repair and vein grafting of the sagittal sinus have been proposed [2, 4, 9, 12–14, 18, 19, 22]. However, we think that the risks correlated with such procedures do not justify their use. The main risk of venous sinus reconstruction is the incidence of delayed thrombosis, which reaches 50% [1, 11, 21]. In addition, grafting adds operating time without guaranteeing sure benefits. Additional operating time is not a marginal problem, because many patients are elderly. Also, most of the experience of sinus reconstructions is still based only on circumstantial cases [2, 4, 9, 12–14, 18, 22].

We always performed a total sinus resection in meningiomas that were infiltrating the anterior third of the SLS, to attempt complete tumour removal without observing venous infarction. In meningiomas infiltrating the middle and posterior SLS segments, our treatment policy provides:

– radical removal of the tumour with resection of the sinus wall only when the sinus is occluded and a collateral venous circle has developed
– marginal sinus resection when the SLS is patent. In this event, we adopt a wait-and-see policy and neuroimaging follow-up as reported in the Materials and methods section

The rationale of our choice is mainly based on the observation that patients with recurrence can undergo one or more additional operations with good results. In our series, 13 patients underwent two operations, five patients underwent three operations, and three patients four operations. Quality of life of these patients was not affected by surgery. Most of the patients returned to their previous activities both after the first and second operations and also after a third or fourth operation.

An important aspect must be considered in cases of patent SLS, about the vein draining into it and passing into/around the tumour, and in cases of complete SLS obliteration, about the compensatory venous channels. The surgeon must always be careful to dissect these veins from the tumour, because severe congestion phenomena may occur. Naturally, this concept influences the surgical treatment, because radical removal is not recommended if important venous vessels cannot be preserved. Preoperative angiography or angio-MRI are very useful, not only to evidence the patency or occlusion of SLS but also for visualising cortical veins draining into the SLS in the case of a patent SLS or important collateral venous pathways in the case of occluded SLS. On the basis of this knowledge, we can choose the best approach to dominate and spare the venous system. Craniotomy should be large enough to expose the proximal and distal ends of the occluded SLS. In our and other series, sacrifice of the patent anterior third of the SLS is not associated with cerebral damage, because of the preservation of the end-to-end anastomoses among the superficial cortical veins. These will act as anastomotic pathways when the anterior SLS is occluded [16].

Another important consideration is the type of collateral vein pathway developed in the case of obliterated SLS. These may be both cortical veins anastomosed with other veins of the cerebrum and meningeal veins anastomosed with other venous channels; dural arteriovenous fistulas are known to develop with sinus occlusion and may pose further risks and complicate treatment [7]. It is then very important to open the dura carefully, because meningeal veins may represent an important part of the collateral venous circulation. Also, it is preferable to sacrifice the bridging veins at the entrance point into the sinus rather than to sacrifice the veins on the cortical surface to preserve the anastomoses among the cortical veins. In our series, we have not observed disability related to the sacrifice of veins.

Our treatment policy is also justified by the observation that the complete resection of the sinus wall does not prevent recurrence at the limits of the dural resection. Although the most frequent site of tumour reappearance is in the same portion in the sinus wall, tumour regrowth may occur through the sinus to another segment, while the primary operating site remains free of recurrence. This is probably due to the development of tumour cells in the meninges outside the limits of macroscopic attachment. Borovich and Doron [5] attributed recurrence to the presence of some neoplastic foci in the dura mater around the insertion zone of the meningioma. This hypothesis is consistent with our data. In the current series, 28% of meningioma recurrences had a location different from the previous one. We agree with Borovich and Doron's statement that a grade 0 (removal of about 4 cm of dura mater around the periphery of the meningioma attachment) should be added to Simpson's scale (Borovich et al. [6]).

In our series, the Simpson grade was a predictor of regrowth/recurrence (we found a statistical significance of complete tumour removal). We observed only one case of dedifferentiation of a previous benign meningioma into an atypical type, and all 328 meningiomas were histologically benign. We do not have an explanation for this is very untypical circumstance. This precluded the possibility of evaluating the role of histology type as a prognostic factor for regrowth/recurrence.

A limit of the present study could be that the use of CT (99 patients) or MRI (229 patients) as early and late postoperative follow-up is not the same to evaluate radical surgery, tumour progression or regrowth. However, the tumour residue, tumour progression or regrowth were always confirmed by surgical reports. In addition, with the advent of MRI, in a further 85 patients followed with CT we introduced an MRI study. In these cases no substantial differences were noted.

In conclusion, our results demonstrate that the extent of removal significantly influences the regrowth or recurrence ($P<0.001$), and re-intervention in patients with meningioma infiltrating, but not obliterating, the SLS does not affect clinical outcome. More than one operation is well tolerated by patients. For this reason, we prefer to leave an eventual residue in place rather than to achieve a complete tumour removal with sinus reconstruction or venous by-pass.

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